Particulate Pollution Trends in the 1980's

by

Matthew E. Kahn, Columbia University

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Matthew E. Kahn[1]

Columbia University

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Abstract

This paper estimates particulate production functions to study how particulates co-move with manufacturing activity after controlling for climate, and regulatory factors. In addition to studying whether more regulated counties enjoy less pollution per unit of economic activity, I also study whether particulate regulation displaces economic growth to less regulated areas.

[1]Assistant Professor of Economics and International Affairs, Columbia University, 420 W. 118th Street, NY. NY. 10027, e-mail: mkahn@mahler.econ.columbia.edu. I thank Dora Costa and two anonymous referees for extensive comments on an earlier draft. All mistakes are mine.

I. Introduction

Particulate concentration levels have fallen across the United States since 1970.[1] Forty six states enjoyed particulate reductions between 1981 and 1987 with a sharp reduction in particulates occurring between 1981 and 1982. This paper uses a large panel data set of ambient particulate readings, economic activity, and regulatory proxies to explore the relationship between county air quality and county economic activity.[2] I test whether the decline in particulates is better explained by declines in manufacturing activity versus declines in pollution per unit of manufacturing. If the decline of manufacturing explains lowered particulates, then this would indicate a "silver lining" of de-industrialization. Since a service economy's output does not create the negative health externalities associated with manufacturing, GNP would be a better indicator of the representative agent's welfare.[3]

The second goal of this study is to quantify particulate regulation's role in lowering county particulate levels. To study the Clean Air Act's impact, I partition all counties into those that were assigned to the non-attainment and the attainment categories in 1977. I study whether more regulated counties have enjoyed greater particulate improvements. It is important to understand why particulates has improved to assess the benefits of environmental regulation. Previous research has

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[1]The EPA estimates that particulate emissions have fallen 62% between 1970 and 1987 (Portney 1990). Crandall (1983) presents evidence on 1970s particulate trends.

[2]Industrial processes account for 35% of particulate emissions and stationary fuel combustion accounts for 26% while highway vehicles account for 18%

[3]Both hedonic studies (Blomquist et. al. 1988, Smith and Hwang 1995) and epidemiological studies (Ostro 1987, Portney and Mullahy 1990, Ranson and Pope 1995) indicate that people value lower particulate levels.

The benefits of the permanent reduction in particulates during the 1980s can be estimated by combining hedonic estimates of the value of life with epidemiology estimates of the mortality costs from particulates. Borrowing from Portney's (1981) study, if one more unit of particulates leads to .5 deaths per 100,000 people per year, then a reduction of eight units saves 10,000 people a year. If the value of life is one million dollars per person, then the yearly value of the reduction is 10 billion dollar.

reported mixed evidence on the benefits of EPA regulation. MacAvoy (1987) finds no evidence that heavily regulated industries pollute less. Henderson (1995) reports that ground level ozone fell by 3 to 8% when a county was switched into non-attainment, more heavily regulated, status. Magat and Viscusi (1991) have examined pulp and paper mills' compliance with water pollution regulation and found that inspections increase future compliance.

In addition to studying the relationship between county manufacturing and particulates in more and less regulated areas, I also study whether particulate regulation has displaced economic growth to less regulated counties. These tests are based on aggregate county manufacturing data and on the microdata set extracted from the Census of Manufacturer's Longitudinal Research Database (LRD). This research adds to Henderson's (1995) recent work on the displacement effects of ozone regulation.

This paper is organized as follows. Section Two presents my data sources. Section Three reports trends in particulates and manufacturing during the 1980s. Section Four presents levels and differenced multivariate particulate regressions. Section Five studies whether Clean Air Act regulation is encouraging the displacement of economic activity to clean counties. Section Six concludes.

II. Data

The particulate data source is the EPA's Aeromatic Information Retrieval System (AIRS) data base. Particulates were sampled in 35% of all counties. The EPA chooses monitoring locations to identify which areas are not in attainment of the Clean Air Act standards so that it can impose more stringent regulation to bring these areas into compliance. EPA monitoring intensity varies across states. In California in 1981, there was one particulate monitoring station for every 161,000 people while in Ohio there was one particulate monitoring station for every 32,000 people.

Monitoring generates a large data base that can be used to study pollution trends. The data contains approximately 25,000 observations and covers all AIRS monitoring stations between 1981 and 1989. As the EPA switched to a PM-10 standard in 1987, many of the particulate monitoring stations were closed down. In 1981, there were 3,742 monitors. Monitoring decreased to 3,083 by 1984 and fell further to 2,163 by 1988. In 1989, there are 1,344 monitor readings reported. Some counties have many monitoring stations. In 1981, 1,108 counties were monitored while by 1987 there were 904 counties monitored and this fell to 561 by 1989. As would be expected, monitoring stations which had higher 1981 particulate readings were less likely to be closed by 1989. I have estimated a logit model of closure probability and found that a monitoring station with a initial reading of 65 milligrams per cubic meter, located in a non-attainment county, had a 42% probability of being closed in 1989. A monitoring station with an initial reading of 55 milligrams per cubic meter, located in an attainment county, had a 59% chance of being closed in 1989.

Two manufacturing data sets are used in this study. The source for both is the Department of Commerce. The first data set is the national REIS data set. For each county from 1969-1992, this data reports county manufacturing employment. I use county yearly manufacturing employment as a proxy for county economic activity.[4] The correlation between county manufacturing employment and county non-manufacturing employment is greater than .9.

The second manufacturing data set is a special extract of Rust Belt plants from the Longitudinal Research Database.[5] This data set of 215,650 plants includes information on the plant's total employment in 1967, 1972, 1977, 1982 and 1987, the plant's SIC code and its state and county location. This micro data is used to study manufacturing plants' survival rate as a function of their two digit SIC code, plant size, and whether the plant is located in a more heavily regulated county. Conditional on surviving, I study plant employment growth in more and less regulated counties.

To proxy for particulate regulation's intensity, I used the 1979 Federal Registar 40 CFR part 81 to assign all counties into two groups; those in attainment and those not in attainment with the Clean Air Act's particulate standard in 1977. Counties not in compliance face stricter regulation to bring them into compliance. Based on this data, 384 counties were assigned to non-attainment status.

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[4]Industrial processes account for 35% of particulate emissions and stationary fuel combustion accounts for 26% while highway vehicles account for 18%.

[5]The Census Bureau has developed a Longitudinal Research Database (LRD) which is a time series of economic variables collected from manufacturing establishments in the Census of Manufacturers and Annual Survey of Manufacturers programs. The LRD file contains establishment level identifying information; basic information on the factors of production and the products produced (LRD Technical Documentation Manual 1992). The data file includes geographical information identifying each plant's state, county, smsa, and place.

All regressions will be estimated separately for the two groups.[6] In 1987, the EPA started to regulate only a subset of smaller particulates, PM-10. From the Clean Air Deskbook, I have listed the roughly 70 counties assigned to the PM-10 non-attainment group. In my particulate data set, 68% of counties were in attainment with the 1977 particulate standard and the 1987 PM-10 standard while 3% were in non-attainment of both standards. Impressively, 90% of all counties that were assigned to the particulate non-attainment category in 1977 were in attainment with the PM-10 standard in 1987. Finally, 4% of counties in attainment in 1977 were not in attainment with the PM-10 standard in 1987.[7]

The climate data source is the NOAA CD-ROM. This data base contains yearly readings on temperature and rainfall at various monitoring stations across each state. I use yearly rainfall as a proxy for county climate. Increased rain should decrease an area's ambient particulate level.

Summary statistics by attainment status are presented in Table One. Non-attainment counties have much higher particulate levels and much higher manufacturing levels. It is also important to note non-attainment counties are heavily over sampled. Roughly 10% of all counties are not in attainment but roughly half of the monitoring stations are in non-attainment areas.

III. Particulate and Manufacturing Trends

Table Two presents quantiles of the particulate distribution for certain years between 1981 and 1989 for all counties and also reports quantiles for those counties that were and were not assigned to non-attainment status.[8] The key point to note is the sharp improvement in particulate levels between 1981 and 1982. If regulation were the sole reason for improvement and regulation

[6]In previous research, I have studied whether Federal and State real per-capita transfers to the state EPA could be used as a proxy for regulatory intensity. Unfortunately, this data represents the transfer for all six pollutants regulated under the Clean Air Act. Thus, California receives the largest per-capita transfers. Even though it has a relatively low particulate level, its ozone problems merit large transfers.

[7]It is relevant to note that roughly two thirds of the PM-10 non-attainment counties are located in western states such as Colorado, Montana, Utah, Wyoming, Arizona, Nevada, Idaho, Oregon, Washington, and California.

[8]Particulate trends in the 1970s are reported in Crandall (1983, p18).

was concentrated on high polluting counties, then we should observe the 25th percentile and the median not changing over time and that the 75th percentile of the distribution is shifting in. Table Two indicates that all percentiles of the particulate distribution decreased between 1981 and 1982. The 25th percentile of the 1981 particulate distribution is greater than the median of the 1989 particulate distribution. The 25th and 75th percentiles of the distribution fell 16% and 14.5%, respectively, between 1981 and 1982.

Suggestive evidence of regulatory success would be if particulates have improved by more in non-attainment than attainment counties. Table Two shows that median particulates have improved in both attainment and non-attainment counties. Between 1981 and 1982, median particulates fell from 55.8 to 46.2 in attainment counties and fell from 62.2 to 53.9 in non-attainment counties. Note that for both sets of counties air quality slightly degraded between 1982 and 1989.

Table Three exploits the panel nature of the data to present a transition matrix of changes in a monitoring station's particulate readings from 1981 to 1987. I have readings in 1981 and 1987 for 1,888 different stations. In 1981, I assign each station to one of ten deciles where #1 is the best air quality and #10 is the worst. Sorting by particulate level in 1987, I reassign each monitoring station to a 1987 decile. Table Three presents the transition matrix where a given (i,j) element of the matrix indicates the percentage of monitoring stations in decile i in 1981 that are in decile j in 1987. The correlation of the ranks between 1981 and 1987 is .75. If the main diagonal of Table Three had all been 1's then this would indicate that all stations preserve rank between 1981 and 1987. In fact, the main diagonal in Table Three does have large values but there is certainly evidence of upward and downward mobility for stations in the middle of the distribution in 1981. Interestingly, the cleanest and dirtiest counties in 1981 are "stuck". For the cleanest 10% of all monitoring stations in 1981, 83% of these stations are in the top two deciles in 1987. For the dirtiest 10% of all monitoring stations in 1981, 82% of these stations are in the bottom two deciles in 1987. Table Two indicates that the distribution at all quantiles shifted in from 1981 to 1982. Table Three indicates that monitoring stations roughly preserved rank between 1981 and 1987.

Table Four presents median state particulate levels in 1981 and presents the growth rate from 1981 to 1982 and from 1982 to 1987. It is interesting to note that particulates fell in 45 of the 48 states between 1981 and 1982 but particulates only fell in 14 states between 1982 and 1987. The state trends do not exhibit a common pattern. For example, Rust Belt states such as Illinois and Indiana experienced sharp reductions in particulates from 1981 to 1982 but then particulate levels remained roughly constant between 1982 and 1987. For other Rust Belt states such as Ohio, Pennsylvania, and West Virginia, particulates continued to decline between 1982 and 1987. The west generally exhibited degradation. Arizona, Idaho, Nevada, Oregon, South Dakota, Washington all suffered increased particulates between 1982 and 1987.

Table Five presents state growth rates in manufacturing employment between 1981 and 1982 and from 1982 to 1987. With the exception of Nevada, every state suffered manufacturing job loss between 1981 and 1982. For example, manufacturing employment declined by 11% in Ohio and 12% in West Virginia. Between 1982 and 1987 only twelve states suffered continued manufacturing decline. Rust Belt employment grew more slowly than states such as Arizona and Nevada that grew at 23% and 24% respectively.[9]

IV. The Relationship Between Particulates and Manufacturing

To study the relationship between particulates and manufacturing, I estimate pollution production functions. My methodology is to regress the log of a county's yearly mean particulate reading (TSP) on year dummies, county manufacturing interacted with the year dummies and climate variables.

$$\log(TSP_{jt}) = c + \sum \gamma_t * Year_t + B_{2t}\, Manuf_{jt} + \sum \phi_t * Manuf_{jt} * Year_t + B_4\, rain_{jt} + \epsilon_{jt} \quad (1)$$

Table Six presents four separate regressions estimates based on equation (1). I estimate separate regressions for attainment and non-attainment counties using least squares and a panel

[9]Duffy (1994) finds that the Manufacturing Belt's share of manufacturing employment fell from 61% to 47% between 1963 and 1987.

estimator that controls for county specific fixed effects.[10] Conditional on the fixed effects, climate, and manufacturing proxies, I assume that the disturbance term is iid.

Estimates of equation (1) control for county levels of economic activity, while estimating how the pollution content per unit of manufacturing has changed over time. Table Six presents the results. The manufacturing coefficient estimates indicate that an extra unit of manufacturing causes more pollution in attainment counties than in non-attainment counties. The manufacturing coefficient is statistically significant at the 5% level in three of the four regressions and is statistically significant at the 10% level for all four regressions. The least squares estimates indicate that an increase of 100,000 more manufacturing jobs in 1981 increases an attainment county's particulate levels by 12.3% and a non-attainment county's particulate level by 4%. Using the panel estimator, the estimates are 20.4% and 8%, respectively. Both sets of estimates indicate that pollution per unit of manufacturing is higher in attainment counties.

The coefficient estimates of manufacturing's impact are useful for simulating the "silver lining" of industrial decline. Between 1981 and 1982, Cook County in Illinois (Chicago) lost 50,000 manufacturing jobs. Given that Cook County was a non-attainment area, the regression estimates indicates that this should translate into a 10% reduction in particulates. Interestingly, Chicago's particulates did fall by 10% between 1981 and 1982. However, between 1982 and 1987 Chicago's manufacturing level fell by 16% but particulates showed little improvement.

The year dummies indicate that particulates fell sharply in both the non-attainment and attainment counties between 1981 and 1982 but the year dummies for both regressions are roughly constant from 1982 to 1989.

Table Six presents no evidence that the pollution per unit of manufacturing is falling over time for either attainment or non-attainment counties. In fact, pollution per unit of manufacturing increases and is statistically significant in 1987-1989. This result is surprising because over time older higher polluting plants might die and be replaced by capital of newer vintages that fall under

[10]County fixed effects are included to control for variation in geography. These fixed effects also control for unobserved county and state specific factors such as regulatory enforcement intensity.

more stringent Clean Air Act new source legislation.[11]

The bottom of Table Six reports F-tests that the county fixed effects are highly statistically significant. Although the county fixed effects are statistically significant, it is interesting to note that the least squares results presented in Table Six yield roughly similar coefficient estimates. I have also estimated this model with state fixed effects rather than county and again found comparable results.

An alternative to estimating equation (1) separately for the attainment and non-attainment counties would be to pool them and include an attainment dummy that equals one if the county was not in attainment in 1979. If this dummy is an exogenous variable then its coefficient would indicate the "treatment effect" of being assigned to the non-attainment category.[12]

A model that attempts to estimate county specific fixed effects and estimate the non-attainment status dummy is not identified. In attempting to estimate the non-attainment status dummy, I included state fixed effects, climate and manufacturing.[13] In results that are available on request, I found that controlling for climate and manufacturing, non-attainment counties have 9% higher particulate levels than attainment counties. I interpret this as evidence that even with state fixed effects, the attainment dummy is correlated with the disturbance term. To control for attainment status endogeneity, I have tried instrumenting for attainment status using a county's manufacturing employment in 1969 and the growth rate of county manufacturing employment from 1969 to 1975, and whether sulfur dioxide was monitored in the county in 1975. Unfortunately, I have found that my two stage least squares estimates are highly sensitive to the set of instruments used and that this set of instruments yields a low R2 (roughly .10) in the first stage.[14] Given the weak explanatory

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[11]Worried that this finding may be explained by the fact that cleaner areas were less likely to monitor particulates in 1989, I estimated this model using only counties that had at least one monitoring station in operation in all years between 1981 and 1989. This balanced panel estimation yielded quite similar results that particulates per unit of manufacturing increased in the late 1980s.

[12]In his ozone study, Henderson (1995) is able to estimate the "treatment effect" of being assigned to non-attainment status because for ozone individual counties have switched from attainment status to non-attainment status and vice-versa.

[13]This model is identified because within almost all states there is variation in county attainment status.

[14]The problem is that attainment status in 1979 depends on manufacturing levels in 1978 and 1979. Unfortunately, these lagged manufacturing county levels are very highly correlated (at .9 or higher) with current county manufacturing levels and current manufacturing levels are a crucial

power of my instruments, I am pessimistic about identifying the counter-factual of how a random county's particulate level would evolve had it been assigned to non-attainment status. The results presented in Table Six should be interpreted as revealing how county particulates have evolved over time conditional on attainment status.[15]

This first set of estimates of the impact of manufacturing on particulates imposed that manufacturing's pollution content does not differ across space. Yet, "Rust Belt" states such as Ohio and Michigan are the home of many of the older manufacturing plants that might have higher pollution levels.[16] To explore this composition effect, I estimated equation (1) for just the "Rust Belt" states.[17] It is relevant to note that 34% of the monitoring stations in my sample are located in these states. Table Seven reports the county panel estimates for the "Rust Belt" sample. Note that the marginal impact of manufacturing on particulates is greater than twice as large for the Rust Belt sample than for the national sample as reported in Table Six. Interestingly, the regression's R2 rise sharply to .34 for this subset of the data.

To further study particulate trends, I estimate a growth rate specification that includes the log of the county's mean particulates in 1981. The regression is presented in equation (2).

$$\Delta\ \log(TSP_{it}) = c + B_2\ \Delta\ \log(Manuf_{it}) + B_3\ \Delta\ \log(rain_{it}) + B_4\ \log(TSP_{i,81}) + \Delta\ V_{it} \quad (2)$$

Analogous to the convergence growth literature, I study particulate growth rates with respect

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variable for explaining current particulate levels.

[15]Analogous to the job training literature, I have estimated the benefits of the program for the set of subjects who chose to take training (those assigned to the more regulated non-attainment group). I have not estimated what the benefits of "training" would have been for a random subject who chose not to take training (a county in the attainment group).

[16]Lugar and Evans (1988) find that plants in the same industry located in different places have different production functions. Garcia-Mila and McGuire (1993) report evidence that state economies are not microcosms of the national economy.

[17]These include; Illinois, Indiana, New Jersey, Michigan, New York, Ohio, Pennsylvania, and West Virginia.

to initial levels while controlling for changes in economic activity.[18] This regression answers whether initially more polluted counties are "catching up" over time to the cleaner counties. If the EPA focuses its regulatory efforts on the highest polluting counties than we would expect to observe convergence. This regression complements the particulate transition matrix presented in Table Three.

Table Eight reports an estimate of equation (2) where I have pooled attainment and non-attainment counties. The dependent variable is the percentage growth of particulates for a given monitoring station between 1981 and 1987. The independent regressors include the growth rate in county manufacturing employment, growth in rainfall and the monitoring station's particulate reading in 1981. I have interacted the growth rate in the manufacturing variable, and the particulate reading in 1981 with county non-attainment status and included the non-attainment dummy as a regressor. A 1% increase in manufacturing employment increases particulates by .1%. Note that the initial particulate level coefficient is significant and negative. This indicates that counties with higher particulate readings in 1981 enjoyed greater improvements in air quality than other counties. Interestingly, this convergence does not differ between attainment and non-attainment counties. Table Eight indicates that the non-attainment variables are jointly insignificant at the 10% significance level.

It is important to note that equations (1-2) simply partition attainment and non-attainment counties without trying to further disaggregate these coarse regulatory categories. A further refinement would be to include a location's income. The impact of regulation may not be uniform across states. Although the Clean Air Act's standards are uniform across states, unobserved enforcement effort can vary.[19] If air quality is a normal good, then richer states will demand higher air quality levels. Following Grossman and Krueger's (1995) recent cross-national study, I constructed a state level particulate panel data set to study the relationship between particulates and real per-capita income. Given that all US states are beyond Grossman and Krueger's estimated per-capita income "turning point", then we would expect to see that increased income lowers particulate

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[18] Barro and Sali-Martin (1993) regress growth rates in state's per-capita income on initial state income and show that in the United States there is evidence that the initially poorer states are slowly converging to the level of the initially richer states.

[19] States have relaxed regulation's stringency when it has affected the survival of important local job providers such as the steel industry (Deily and Gray 1991).

levels. Evidence against this hypothesis is that particulates improved during the 1981 recession and actually increased slightly as the economy grew in the 1980s. The estimates of the state level panel are presented below;

$$\log(TSP) = \underset{(.23)}{4.18} - \underset{(.02)}{.14}*(Not1981) + \underset{(.002)}{.005}*Manuf - \underset{(.0004)}{.003}*Rain - \underset{(.04)}{.0013}*Inc$$

N = 428 and R2 = .18

The standard errors are presented in the parentheses. I find that income has a statistically insignificant impact on particulates.

To summarize this section's several findings, manufacturing does increase particulates but there is little evidence pollution per unit of manufacturing decreased more quickly in more regulated counties. The year dummies in the levels regressions indicate that controlling for climate, and manufacturing levels, particulates fell sharply from 1981 to 1982 in both attainment and non-attainment counties. Real income does not play a role in explaining improvements in the 1980s.

Reduced electric utility emissions may explain part of the overall decline in particulates between 1981 and 1982. Freedman and Jaggi (1994) present a case study analysis of changes in air pollution emissions for 105 electric utilities between 1975 and 1987. To reduce particulate, sulfur dioxide, and nitrogen oxide emissions, utilities adopted electrostatic precipitators and burnt lower sulfur coal. Although total coal consumption grew for most of these plants, particulate emissions fell by over 90% at several of these plants. Using Freedman and Jaggi's data, I identified fourteen very large electric utility plants that had greatly reduced their particulate emissions. For these plants, I found evidence that the county they were located in was more likely to be in attainment of the 1987 PM-10 standard than the 1977 particulate standard. In 1977, 43% of the plants were located in counties not in compliance. In 1987, all of these counties were in compliance with the PM-10 standard. This contrasts with 38% for 1977 and 7.4% in 1987 for counties that did not have one of these plants.

V. Displacement of Economic Activity

Air quality can improve because pollution per unit falls or because the level of economic activity decreases. Environmental regulation might reduce air pollution through both mechanisms.

Directly, through lowering source pollution per unit of activity and indirectly by displacing activity to less regulated areas. This spatial effect is analogous to the vintage effect discussed in Gruenspecht (1981).

A growing literature has studied regulation's spatial and temporal substitution effects.[20] Stringent Clean Air Act regulation may lead to cleaner non-attainment counties by deflecting activity to non-monitored and attainment counties. The absence of air quality monitoring in certain counties may encourage economic growth. The EPA assumes that counties it does not monitor are in compliance with Clean Air Act Standards. It is reasonable to assume that less monitored counties are less regulated. If this lowers the cost of producing a product, then a producer may choose to locate there. To study this, I regress manufacturing growth between 1981 and 1988 on county attainment status and on whether particulates are monitored in the county.

Table Nine reports these results. The left column presents county manufacturing growth between 1981 and 1982. The county's growth rate in non-manufacturing employment is included as a control. I find that the presence of a monitoring station does not affect county manufacturing growth but that non-attainment counties experienced 3% lower manufacturing growth. Between 1982 and 1987, I find that counties that monitor particulates and were not in attainment in 1977 experienced 11% lower manufacturing growth. Counties that were attainment and that were not monitored grew 2% faster. The right column of Table Nine is identical to the middle column but now I also estimate state fixed effects. Controlling for state effects, the displacement effect grows. Counties which contain at least one monitoring station and are not in attainment suffered 14% lower manufacturing growth between 1982 and 1988 than counties which did not monitor and were in attainment.[21]

Table Nine's findings are based on aggregated data. A county experiencing manufacturing

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[20]McConnell and Schwab (1991) found little evidence of spatial variation in environmental regulation's intensity affecting manufacturing firms' location decisions. Maloney and Brady (1988) and Nelson, Tietenberg and Donihue (1993) report evidence that more regulated electric utilities are substituting toward older vintage capital that faces less regulatory constraints.

[21]One interesting hypothesis is that starting in 1987 as the particulate standard was phased out and the PM-10 standard was brought in, that only counties that were not in attainment with the 1987 PM-10 standard should suffer manufacturing losses regardless of their initial particulate regulatory status. Future research could use the 1987 and the 1992 Census of Manufacturing data to study this.

job loss could be losing jobs at the extensive or the intensive margins. Existing plants may be closing or surviving plants might be growing slower than they would have in a less regulated environment.[22]

The Census of Manufacturer's LRD microdata offers an opportunity to explore each individual manufacturing plant's probability of closing over a five year window and, conditional on not closing, its percentage growth. I study closing probabilities and plant employment growth as a function of plant size, industry, and whether the plant is located in an attainment county.[23] Table Ten's left two columns present the predictions from a logit model. For each two digit industry, I estimate the probability that a plant open in 1977 was still open in 1982. The explanatory variables are the plant's total employment in 1977, its employment squared, a dummy indicating whether the plant was alive in 1967 and a dummy indicating whether the plant was located in an attainment county. I use the coefficient estimates to predict each plant's probability of closing for a plant with 100 employees by 2 digit industry by county attainment status. Plants located in non-attainment counties are less likely to close for 20 of the 23 industries. For example, for primary metals industry (SIC 33), the same plant located in a non-attainment county had a 5.6% chance of closing between 1977 and 1987 while if it had been in an attainment county its probability would have been 6.8%. These findings rule out that non-attainment counties are improving at a higher rate than attainment counties because of the death of older plants or because highly polluting industries such as steel (SIC 33) are dying faster in the more regulated areas.

To study plant level employment growth for those plants that do not close, I estimate a simple growth rate regression presented in equation (3).

$$\log(Emp_{ij,87}/Emp_{ij,77}) = \alpha + \alpha_2 * Emp_{ij,77} + \alpha_3 * Emp^2_{ij,77} + \alpha_4 * NonAttain_j + U \tag{3}$$

This regression controls for plant size, plant vintage and its county's attainment status. The right

[22]Plants might be choosing not to locate in more regulated counties. A thorough analysis of this discrete choice of where to locate a branch plant is beyond the scope of this paper. This paper focuses on how county particulate attainment status affects growth of incumbent firms.

[23]Dunne, Roberts, and Samuelson (1988, 1989) have also used the LRD to study the probability of plants closing and growing. They did not include regulatory proxies in their analysis.

column of Table Ten presents the coefficient on the dummy for non-attainment by two digit SIC. The estimates are negative and statistically significant. For example, SIC 33 plants in non-attainment areas grew by 10% less than the same plant if it had been located in an attainment area. My plant level estimates suggest that plants in non-attainment areas are less likely to close but conditional on staying open grow more slowly than their counterparts in attainment counties. One explanation for this is that strict environmental regulation of new sources in these counties conveys some monopoly power to the incumbents. The intensive margin findings do support Henderson's (1995) findings on the displacement effects of ozone regulation.

In estimating equation (1), the relationship between particulates and manufacturing, I assumed that the current level of manufacturing activity is not caused by current particulate levels.
This section's estimates indicate that manufacturing activity is slightly reduced by current regulation levels. Thus, one might argue that there is a simultaneity problem when trying to estimate the impact of manufacturing activity on air quality. In response to this claim it is important to note that the estimated impact of environmental regulation on manufacturing activity is statistically significant but in absolute terms not very large. Second, it is quite reasonable to assume that environmental regulators react on a lag. A county's current particulate regulation in 1982 depends on its particulate levels in previous years. Given this lagged structure, even if current manufacturing levels were a function of current regulation, manufacturing levels would not depend on current particulate levels.

VI. Conclusion

Using a county level panel data set, this paper has documented the relationship between manufacturing activity and particulates. Although increases in manufacturing do have a statistically significant impact on particulates, there is little evidence that pollution per unit of manufacturing activity declined during the 1980s. Surprisingly, I find no evidence that particulates per manufacturing job fell faster for more regulated counties than for counties not assigned to the Clean Air Act's non-attainment group.

This paper reported county and plant level evidence that particulate regulation has slightly lowered economic activity. These findings add to Henderson's (1995) recent work on the displacement effects of ozone regulation. Whether this economic displacement has high private costs depends on how substitutable are attainment and non-attainment areas for profit maximizing firms.[24] The counter-factual that must be answered is; what is the producer surplus lost when plants are discouraged from locating in non-attainment areas?

By combining this paper's estimates of the relationship between manufacturing activity and particulates with existing hedonic and contingent valuation studies on the benefits of reduced air pollution, future research can conduct improved green accounting exercises on the net social costs of reduced manufacturing activity in the heavily populated Rust Belt. Such estimates of the social benefits could be compared to the private costs suffered by displaced manufacturing workers.

[24]Little research has tried to estimate the additional cost a firm incurs by operating in a non-attainment area. Researchers have stressed energy and labor costs as more important considerations than environmental regulation in affecting plant locational choice. Surprisingly, Crichfield (1990) reports that industry are not more likely to vacate unionized sectors.

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Table One

Summary Statistics

variable	attainment sample	non-attainment sample
particulates	50.4 (16.8)	58.1 (16.0)
manufacturing employment (100,000s)	.11 (.24)	.29 (.71)
rain	39.5 (18.3)	37.5 (15.7)
observations	5874	2498
The unit of analysis is a county in a given year.		

Table Two

The Temporal Distribution of Particulates

	1981	1982	1985	1989
25th percentile tsp	48.9	41.1	41.8	39.5
median tsp	58.5	49.8	50.3	47.8
75th percentile of tsp	71.6	61.2	62.4	58.9
median for attainment counties	55.8	46.2	48	49
median for non-attainment counties	62.2	53.9	52.6	56.8
75th percentile for attainment counties	66.9	56.1	57.8	59.4
75th percentile for non-attainment counties	75.5	64.5	65.5	68.4

Table Three

Particulate Transition Matrix

	1987 Decile Ranking									
1981 Decile Ranking	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
#1	.66	.17	.06	.05	.02	.02	.02	.01	.01	0
#2	.17	.34	.21	.11	.07	.05	.02	.02	.01	.01
#3	.07	.19	.23	.22	.13	.06	.05	.05	.01	0
#4	.03	.10	.18	.21	.20	.14	.05	.03	.05	.01
#5	.02	.07	.10	.13	.21	.19	.13	.09	.05	.01
#6	.01	.05	.11	.13	.10	.20	.17	.12	.09	.03
#7	.02	.04	.06	.07	.14	.15	.18	.20	.10	.05
#8	.01	.02	.01	.04	.09	.10	.21	.27	.16	.10
#9	0	.02	.02	.04	.05	.05	.12	.20	.34	.17
#10	.01	.01	.03	.01	.01	.03	.05	.04	.19	.63

Panel data by monitoring station on transition over time. Quantile #1 are the cleanest counties, quantile #10 are the dirties. For 1981 and 1987, 1888 data points. in 1981 assign each monitoring station to one of ten deciles. the repeat in 1987 and study the transition matrix. For example, the reading in the matrix for 1981 decile #6 and 1987 decile #4 is .13. This indicates that 13% of the sample in the 6th decile in 1981 improved in air quality up to the #4 decile by 1987.

Table Four

Pollution Trends By State

State	Median TSP in 1981	% change 1981-1982	% change 1982-1987	State	Median TSP in 1981	% change 1981-1982	% change 1982-1987
Alabama	56.6	-22	10	Montana	50.1	-20	12
Alaska	65.9	-0	-27	Nebraska	65.5	-11	6
Arizona	79.3	-27	36	Nevada	66.2	-20	45
Arkansas	57	-19	9	New Hampshire	51.5	-18	5
California	67.2	-11	5	New Jersey	51.3	-15	34
Colorado	78.2	-16	5	New Mexico	82.2	-18	-12
Connecticut	44.9	4	-0	New York	48.9	-9	10
Delaware	56.6	-22	3	North Carolina	56.2	-19	6
Florida	53	-27	13	North Dakota	56.2	-28	-1
Georgia	57	-20	3	Ohio	64.4	-16	-4
Hawaii	-	-		Oklahoma	65.2	-10	-13
Idaho	90.5	-32	14	Oregon	49.6	1	24
Illinois	66.2	-16	3	Pennsylvania	63.4	-16	-7
Indiana	63.7	-18	4	Rhode Island	51.5	-14	13
Iowa	63.8	-12	2	South Carolina	54.4	-25	17
Kansas	68.9	-3	-5	South Dakota	56.6	-22	21
Kentucky	64.6	-25	17	Tennessee	59.1	-20	6
Louisiana	61.6	-17	-7	Texas	66.4	-3	-13
Maine	42.8	2	-11	Utah	65.2	-13	-6
Maryland	58.1	-12	5	Vermont	58.1	-20	-5
Massachusetts	52.1	-15	5	Virginia	50.9	-14	7
Michigan	53.5	-10	5	Washington	63.7	-14	15
Minnesota	62.5	-17	5	West Virginia	66.1	-11	-18
Mississippi	59.9	-23	10	Wisconsin	47.5	-13	10
Missouri	64.9	-23	13	Wyoming	45.7	-14	8
units are micrograms per cubic meter							

Table Five

Manufacturing Trends By State

State	% change 1981-1982	% change 1982-1987	State	% change 1981-1982	% change 1982-1987
Alabama	-7	10	Montana	-11	5
Alaska	-	-	Nebraska	-7	6
Arizona	-4	23	Nevada	6	24
Arkansas	-7	12	New Hampshire	-4	7
California	-4	9	New Jersey	-6	-6
Colorado	-1	1	New Mexico	-1	13
Connecticut	-5	-7	New York	-6	-9
Delaware	-4	3	North Carolina	-5	9
Florida	-2	16	North Dakota	-3	8
Georgia	-4	15	Ohio	-11	0
Hawaii	-		Oklahoma	-9	-13
Idaho	-9	14	Oregon	-8	12
Illinois	-9	-9	Pennsylvania	-9	-10
Indiana	-10	5	Rhode Island	-8	0
Iowa	-11	1	South Carolina	-6	3
Kansas	-10	4	South Dakota	-5	18
Kentucky	-9	7	Tennessee	-8	7
Louisiana	-8	-18	Texas	-6	-10
Maine	-4	-3	Utah	-4	9
Maryland	-6	-3	Vermont	-5	4
Massachusetts	-4	-6	Virginia	-4	8
Michigan	-10	11	Washington	-5	11
Minnesota	-5	10	West Virginia	-12	-11
Mississippi	-8	13	Wisconsin	- 8	6
Missouri	-6	4	Wyoming	-8	-4

Table Six

County Particulate Regressions

Dependent variable is the log of a county's yearly weighted average particulates

variable	attainment sample no fixed effects	attainment sample with fixed effects	non-attainment sample no fixed effects	non-attainment sample fixed effects
manuf	.12*	.20*	.04*	.08~
1982 year dummy	-.19**	-.17**	-.16**	-.16**
1983 year dummy	-.17**	-.16**	-.15**	-.14**
1984 year dummy	-.14**	-.13**	-.15**	-.16**
1985 year dummy	-.18**	-.19**	-.17**	-.18**
1986 year dummy	-.16**	-.20**	-.20**	-.20**
1987 year dummy	-.12**	-.18**	-.18**	-.19**
1988 year dummy	-.14**	-.18**	-.14**	-.16**
1989 year dummy	-.20 **	-.23**	-.18**	-.20**
Manuf * 1982 dummy	.07	.07*	.002	.02
Manuf * 1983 dummy	.04	.05	.02	.02
Manuf * 1984 dummy	.05	.04	.01	.02
Manuf * 1985 dummy	.07	.08**	.02	.02
Manuf * 1986 dummy	.06	.11**	.02	.02
Manuf * 1987 dummy	.06	.12**	.03	.03**
Manuf * 1988 dummy	.07	.11**	.03	.03**
Manuf * 1989 dummy	.10	.14**	.04	.04**
rain	-.002**	-.004**	-.003**	-.004**
constant	4.05		4.28**	
observations	5842	5842	2498	2498
R2	.05	.18	.11	.23

~ indicates statistical significance at the 10% level, * significance at the 5% level, and ** significance at the 1% level.
Fixed effect F-test for attainment counties F(892,4931) = 24.2, p-value = .00, Fixed effect F-test for non-attainment counties F(309,2170) = 23.7, p-value = .00.

Table Seven

"Rust Belt" County Particulate Regressions

Dependent variable is the log of a county's yearly weighted average particulates		
variable	attainment sample with fixed effects	non-attainment sample fixed effects
manuf	.44**	.21**
1982 year dummy	-.15**	-.17**
1983 year dummy	-.19**	-.17**
1984 year dummy	-.15**	-.20**
1985 year dummy	-.22**	-.23**
1986 year dummy	-.23**	-.25**
1987 year dummy	-.18**	-.21**
1988 year dummy	-.14**	-.15**
1989 year dummy	-.30**	-.21**
Manuf * 1982 dummy	.06	.04~
Manuf * 1983 dummy	.07	.07**
Manuf * 1984 dummy	.09*	.07**
Manuf * 1985 dummy	.16**	.08**
Manuf * 1986 dummy	.16**	.07**
Manuf * 1987 dummy	.19**	.09**
Manuf * 1988 dummy	.18**	.09**
Manuf * 1989 dummy	.35**	.13**
rain	.002**	-.002**
observations	1016	1090
R2	.32	.34

~ indicates statistical significance at the 10% level, * significance at the 5% level, and ** significance at the 1% level.
Fixed effect F-test for attainment counties F(169,828) = 30.1, p-value = .00, Fixed effect F-test for non-attainment counties F(136,935) = 18.0, p-value = .00.

Table Eight

Growth in County Particulates 1981 to 1987

independent variables	beta (se)
growth in manufacturing	.10 (.034)
growth in rainfall	-.05 (.04)
log of particulate level in 1981	-.26 (.033)
county non-attainment dummy	.26 (.26)
county non-attainment dummy interacted with growth in manufacturing	.042 (.06)
county non-attainment dummy interacted with log of particulates level in 1981	-.05 (.06)
constant	.90 (.14)
obs	824
R2	.13

Standard errors in parentheses. The dependent variable is the growth rate from 1981 to 1987 in county weighted mean particulates. An F-test testing whether the non-attainment regressors are jointly insignificant cannot be rejected at the 10% level. F(3,818)=1.86, prob >F = .134

Table Nine

Growth in Manufacturing Employment

The dependent variable is the growth rate in county manufacturing employment.			
	Manufacturing growth 1981-1982	Manufacturing growth 1982-1988 no state fixed effects	Manufacturing growth 1982-1988 with state fixed effects
constant	-.07 (.004)	.07 (.008)	-
non-attainment dummy	-.03 (.01)	-.08 (.02)	-.09 (.02)
growth in non-manufactoring employment	.41 (.06)	.53 (.046)	.48 (.05)
monitor dummy	.001 (.006)	-.04 (.02)	-.05 (.016)
Obs	2956	2936	2936
R2	.02	.05	.13
standard errors in parentheses			

Table Ten

Employment Changes at the Intensive and Extensive Margin by Two Digit SIC Industry

SIC Two Digit	Prob Plant Close 1977-1987 in a Non-Attainment County	Prob Plant Close 1977-1987 in an Attainment County	Gap	Predicted employment growth gap between non-attainment and attainment counties for surviving plants
20 (Food)	7.2	9.5	-2.3**	-.09**
22 (Textile Mill)	7.1	10.8	-3.7**	-.002
23 (Apparel and Other Textiles)	9.7	16.2	-6.5**	.03
24 (Lumber and Wood)	7.7	8.7	-1	-.002
25 (Furniture and Fixtures)	14.2	4.8	9.4**	-.03
26 (Paper)	6.3	6.7	-.4	-.07**
27 (Printing and Publishing)	2.6	3.6	-1**	-.04
28 (Chemicals)	7.8	10.7	-2.9*	-.11**
30 (Rubber and Plastics)	5.1	5.9	-.8	-.09**
31 (Leather)	12.1	12.2	-.1	-.22
32 (Stone, Clay, Glass)	7.7	11.9	-4.2**	-.01
33 (Primary Metals)	5.6	6.8	-1.2	-.10**
34 (Fabricated Metals)	4.8	7.1	-3.3**	-.06*
35 (Industrial Machinery)	4.2	6.5	-2.3	-.10**
36 (Electronics)	3.1	3.5	-.4	-.05
37 (Transportation Equipment)	7.9	9.9	-2	-.08
38 (Instruments)	6.7	8.3	-1.6	-.16*
39 (Misc.)	5.2	8.4	-3.2**	-.09

The plant level closing probabilities are generated by estimating a separate logit model for each two digit SIC. For attainment and non-attainment counties, I predict probabilities for a firm with 100 employees for plants built after 1970. For plants that do not close between 1982 and 1987, I estimate plant growth rates as given in equation (3). * indicates statitistical significance at the 5% level and ** indicates statistical significance at the 1% level. Gap is defined as the left column minus the second to left column.

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